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EMBEDDED HEAT SPREADER BALL GRID ARRAY

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FIELD OF THE INVENTION

The present invention relates to semiconductor chip packages, and more specifically, to ball grid array packages with heat spreaders.

BACKGROUND OF THE INVENTION

In general, semiconductor packages are used to protect a semiconductor die in a package body and to provide connection points for connecting the packaged die to external devices and circuitry. Ball grid array (BGA) packages are currently used to handle the high density and high pin-count of semiconductor die. In a typical BGA package, the semiconductor die is mounted to the top surface of a printed circuit board (PCB) type substrate. The die is wire bonded to electrical traces on the top surface of the substrate. The bond wires and die are then typically encapsulated for protection. Solder balls are bonded to the electrical traces on the bottom surface of the substrate to provide electrical connection to an underlying device, such as a PCB.

During operation of the integrated circuit, heat is generated by the die which must be removed from the package. Many packages use heat dissipation elements, such as heat slugs, heat spreaders, and heat sinks, attached or coupled to the die. These elements can be

made of materials, such as aluminum, copper, steel, and alloys, which spread and remove the heat from the device.

With a cavity-down configuration, in which the die face is facing down towards the ball grid array, the die and bond wires are encapsulated in the cavity, and a heat dissipation element is typically attached to the back side of the die to form the top of the chip package. These types of configurations have high package or substrate profiles as well as high assembly costs. With a cavity-up configuration, in which the die face is facing up and away from the ball grid array, a chip lid is secured over the die and bond wires to dissipate heat generated by the circuit. However, these "drop-in" lids result in a high thermal resistance between the die and the heat spreader.

Accordingly, a ball grid array package with a heat dissipating element is desired without the disadvantages discussed above with conventional packages.

SUMMARY OF THE INVENTION

In accordance one aspect of the invention, a high thermal conductivity heat spreader or slug is attached directly to the face of a cavity-up ball grid array (BGA) package with a thin adhesive layer. The heat spreader and underlying die are then completely enclosed by an encapsulant.

In one embodiment, the shape of the heat spreader approximately conforms to the topographical profile of the underlying die, substrate, and die-to-substrate connections, such as bond wires, where the outer

portions of the heat spreader substantially overlie all exposed areas of the substrate. In another embodiment, the outer portions of the heat spreader only overlie portions of the substrate extending from the four sides of the die, i.e., the corner portions of the substrate remain exposed.

Attaching the heat spreader directly to the die surface results in a very low thermal resistance at interface between the die and heat spreader. The design of the heat spreader then allows heat to be spread laterally in the package and dissipated through the top and bottom surfaces of the package. Completely embedding the heat spreader in the encapsulant with only a thin layer of material over the upper portions of the heat spreader and between the heat spreader and the substrate accommodates mechanical tolerance stackup of die thickness, bondline thickness, and heat spreader thickness without sacrificing thermal performance. This also maximizes the available area for package marking and improves the cosmetic appearance of the package.

The present invention will be more fully understood when taken in light of the following detailed description taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is side view of a ball grid array (BGA) package according to one embodiment of the present invention.

Fig. 2 is a top view of a heat spreader from the BGA package of Fig. 1, according to one embodiment.

Fig. 3A is a top view of a heat spreader according to another embodiment of the invention.

Fig. 3B is a side view of a BGA package and the heat spreader of Fig. 3A along sectional line I-I'.

Fig. 3C is a side view of a BGA package and the heat spreader of Fig. 3A along sectional line II-II'.

Fig. 4 is a side view of a flip chip BGA package according to another embodiment of the present invention.

Use of the same or similar reference numbers in different figures indicates same or like elements.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

In accordance with one aspect of the present invention, a heat spreader or slug is attached directly to the face of a die in a die-up ball grid array (BGA) package and the heat slug, die, and bond wires completely encapsulated.

Fig. 1 is a side view of a BGA package 10 according to one embodiment of the present invention. BGA package 10 includes a semiconductor die 12 and an array of solder balls 14 electrically coupled to a substrate 16. Substrate 16 includes (not shown) multiple patterned dielectric and conductive layers, with vias and other interconnections providing connections between the various layers and to the top and bottom surfaces of the substrate. Die 12 is attached to the upper surface of substrate 16, such as by a silver epoxy, and electrically connected to traces on the upper surface of substrate 16, such as with bond wires 18. Solder balls 14 are set on the bottom surface of substrate 16 to provide electrical

connection between external circuitry, such as a printed circuit board (not shown), and die 12.

A heat spreader or slug 20 is then attached to the upper or active surface of die 12, such as with a thin adhesive 22 (e.g., on the order of 1 mil or less). The thin layer of adhesive provides a very low thermal resistance between the heat generating portion of die 12 and heat spreader 20. Adhesive 22 can be filled with a material, such as silver, for increased thermal conductivity, provided that the reliability of the interface between die 12 and heat spreader 20 is maintained. Heat spreader 20 is formed from a material with high thermal conductivity or heat transfer coefficient, such as, but not limited to, copper, copper/molybdenum alloys, copper/tungsten alloys, aluminum, aluminum nitride, beryllium oxide, and steel.

After adhesive 22 is cured, die 12, bond wires 18, and heat spreader 20 are encapsulated using a conventional process, such as transfer molding or an encapsulant dispense process. For example, a dielectric material, such as an uncured silica or glass filled epoxy, is formed over die 12, bond wires 18, and heat spreader 20. A thin layer (e.g., 6 ± 3 mil) of epoxy covers the uppermost surface of heat spreader 20. The epoxy is then heated and cured, resulting in an encapsulant 24 that completely covers heat spreader 20.

As seen from Fig. 1, heat spreader 20 is shaped to approximately conform to the profile of the underlying structure. In this example, heat spreader 20 has an interior portion 26 that is approximately parallel to the face of die 12, a first angled portion 28 that extends upwards away from die 12, an upper portion 30

that flattens out above the top of bond wires 18, a second angled portion 32 that extends approximately along bond wires 18, and an outer portion 34 that is approximately parallel to the upper surface of substrate 16. Other shapes are also suitable, provided only a thin adhesive attaches the heat spreader to the die face. In some embodiments, the portion of heat spreader 20 directly over the die is approximately 10 mil in thickness. Fig. 2 is a top view of one embodiment of heat spreader 20. In this embodiment, heat spreader 20 is rectangular or square shaped and overlies substantially all of the exposed upper surface of substrate 16. This design maximizes heat transfer capability due to a large flange area that extends to outer portions of substrate 16.

Fig. 3A is a top view of another embodiment of a heat spreader 40 according to the present invention. Figs. 3B and 3C are side views of a BGA package 42 using heat spreader 40 of Fig. 3A. Heat spreader 40 shown in Figs. 3B and 3C is along sectional lines I-I' and II-II', respectively, of Fig. 3A. Similar to heat spreader 20 of Figs. 1 and 2, heat spreader 40 has interior portion 26 overlying the face of die 12, first angled portion 28 that extends upwards away from die 12, and upper portion 30 that flattens out above the top of bond wires 18. However, second angled portion 32 and outer portion 34 of heat spreader 40 only extend laterally from the sides of upper portion 30, instead of along the entire circumference of upper portion 30 as in Fig. 2. Thus, as compared with heat spreader 20 of Figs. 1 and 2, heat spreader 40 of Figs. 3A-3C has a smaller flange area, but is likely to have better mold

process yields due to better cavity-fill characteristics.

While the above embodiments describe a heat spreader attached to the face of a die, advantages of the present invention can also be obtained by attaching a heat spreader to the back of a die, as shown in Fig. 4. Fig. 4 is a side view of a flip chip BGA package 50 according to another embodiment of the invention. Flip chip BGA package 50 includes a multi-layer substrate 52 in which electrical connections can be made between the upper and lower surfaces of substrate 52, such as with vias and traces (not shown). A face down die 54 is electrically coupled to the upper surface of substrate 52, such as through solder bumps 56. An array of solder balls 58 allows signals from die 54 to be coupled to external circuitry, such as an underlying PCB. Package 50 can be underfilled with an epoxy resin 60 for relieving stresses resulting from the thermal mismatch between die 54 and substrate 52 and for preventing moisture from reaching the active surface or face of die 54.

A heat slug or spreader 62 is attached directly to the back of die 54, such as with an adhesive as discussed above. A stiffener ring 64 or other suitable layer is attached to substrate 52 such that the top surface of ring 64 is slightly above the top of heat spreader 62. An encapsulant 24, such as an epoxy, then completely covers die 54 and heat spreader 62.

The above-described embodiments of the present invention are merely meant to be illustrative and not limiting. It will thus be obvious to those skilled in the art that various changes and modifications may be

made without departing from this invention in its broader aspects. For example, although the heat spreaders discussed above are shown as solid elements, slots can be added to the heat spreaders to improve mold flow. Further, the heat spreaders can be grounded if the electrically conductive epoxy is dispensed on the substrate surface, and the substrate has exposed metal features tied to ground. Grounding the heat spreader improves electrical performance, as well as EMI shielding. Therefore, the appended claims encompass all such changes and modifications as fall within the true spirit and scope of this invention.